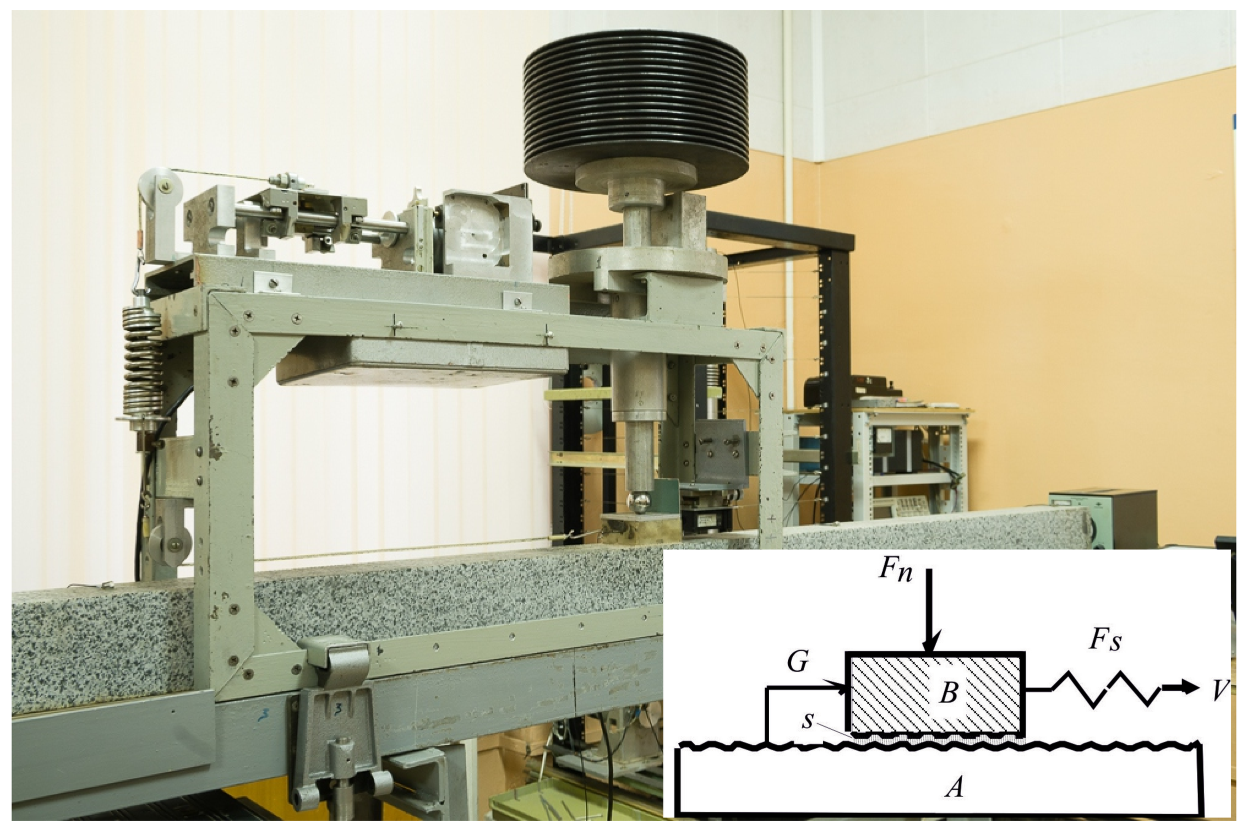
ABOUT THE POSSIBILITY OF TRANSFORMATION OF SHEAR DEFORMATION MODES

Alexey A. Ostapchuk, G.G. Kocharyan, D.V. Pavlov, and V.K. Markov
Institute of Geosphere Dynamics RAS, Moscow, Russia, email: ostapchuk@idg.chph.ras.ru

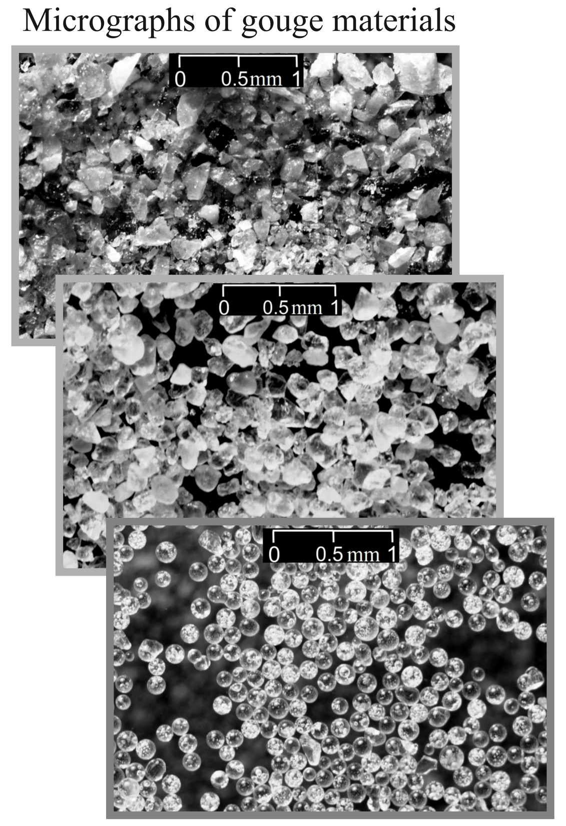
Abstract. We present the results of laboratory experiments aimed to study the formation of different slip modes on the interfaces in a rock massif such as aseismic creep, stick-slip, and periodic slow-slip events. It is shown that the spectrum of possible deformation events on the discontinuity is governed by mesoscale structure of the gouge rather than by its microscopic strength characteristics.

We consider the effects of low-amplitude vibrations on stressed fractures and the influence of viscosity of wetting agent on the frictional interaction mechanism. It is shown that, depending on the mode of deformation, the vibration impact can either reduce or boost the amplitude of separate events. We found out the new effect of radical changing deformation mode at reaching by viscosity of the agent a critical value.

Experimental procedure.



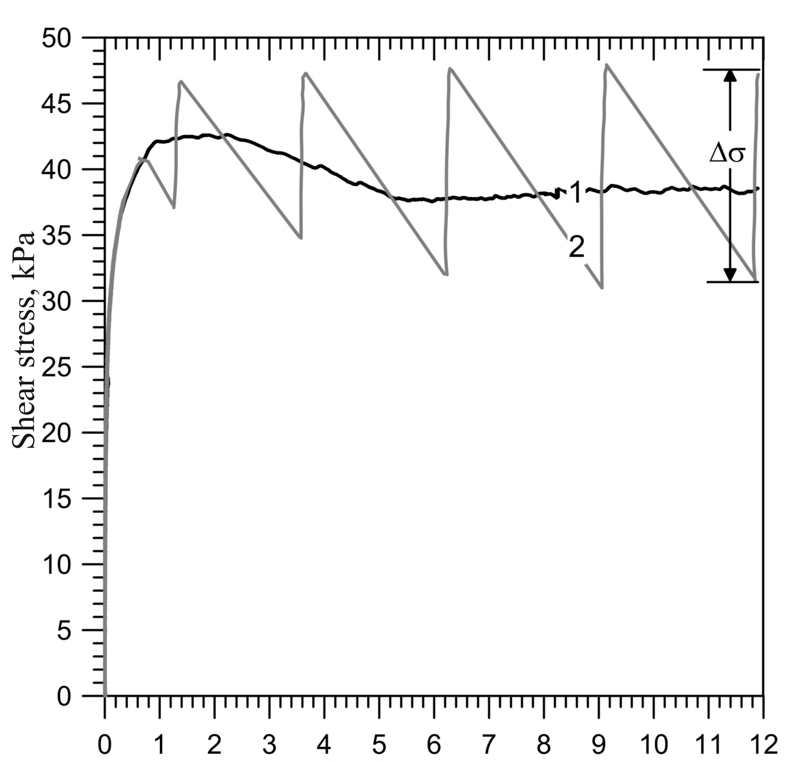
Micrographs of gouge materials

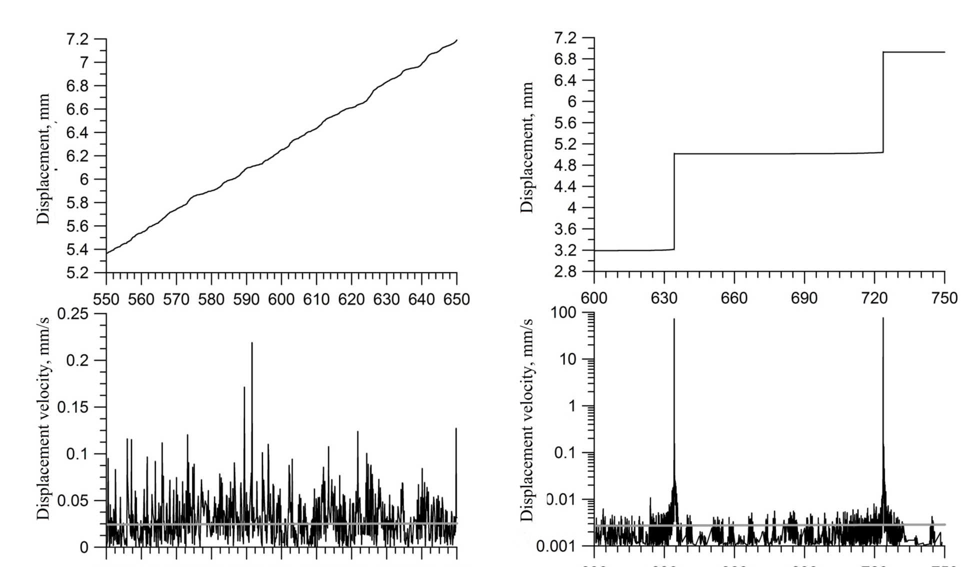


The laws of formation of different deformation modes were studied with a classical experimental setup of a slider model in which a block slides along the interface under applied shear load. Granite block *B* rested upon a fixed granite substrate *A*. The contact gap between rough surfaces was filled with a layer of discrete material *s*.

The layer thickness was about 2.5 mm. Normal load varied from 10^4 to $2 \cdot 10^5$ Pa. The displacement of the block relative to the base were measured in the frequency band of 0 to 5 kHz with an accuracy of 0.1 mkm (ILD2220-10). The crack was filled with quartz sand, glass balls and "granite crumbs". The average grain size of all gouges was 300-330 mkm. The shape for different materials was absolutely different. Granite crumbs were angular with sharp edges, sand grains were more rounded, and glass balls were round in shape.

Examples of different sliding modes





Stable sliding
Stick-slip

It is convenient to use the peak rate of sliding as a key parameter to characterize the shear deformation implemented in our experiment.

Conditions for the occurrence of different deformation modes.

By using the mixtures of the different materials, we simulated a wide range of sliding modes: stable sliding, which corresponds to aseismic creep on the natural fault zones; displacement by a series of slow slips—quiet or slow earthquakes; and stick-slip motion with a different amplitude of seismic moment, which is released by a single event (different scale earthquakes).

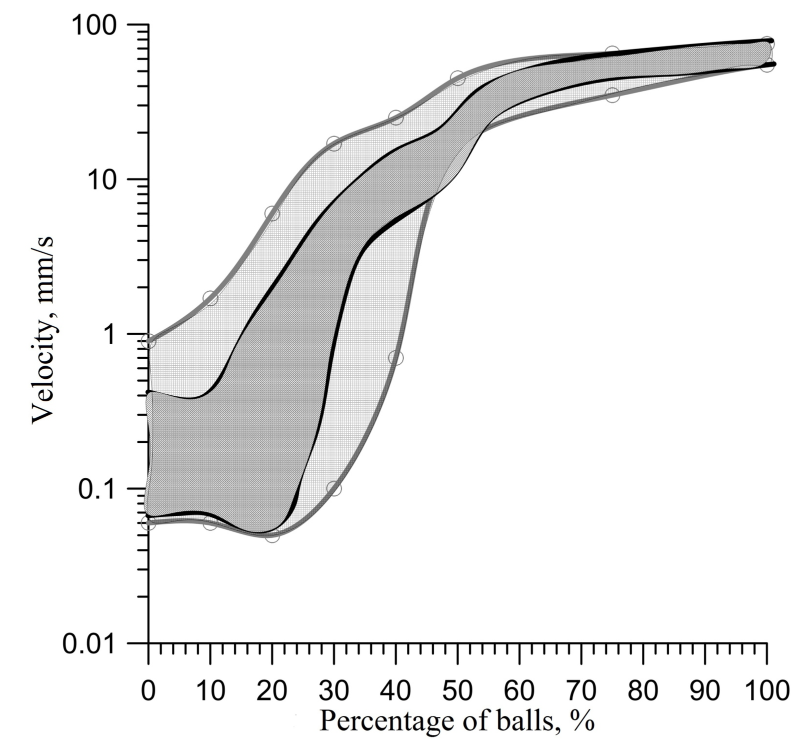


Figure 1. Variation ranges of sliding velocity at varying gouge structure. the light region corresponds to granite crumbs with glass balls added, the dark region corresponds to quartz sand with glass balls

The sliding mode is strongly affected by gouge structure. The growing percentage of smooth particles causes variation in friction resistance from stable sliding to stick-slip.

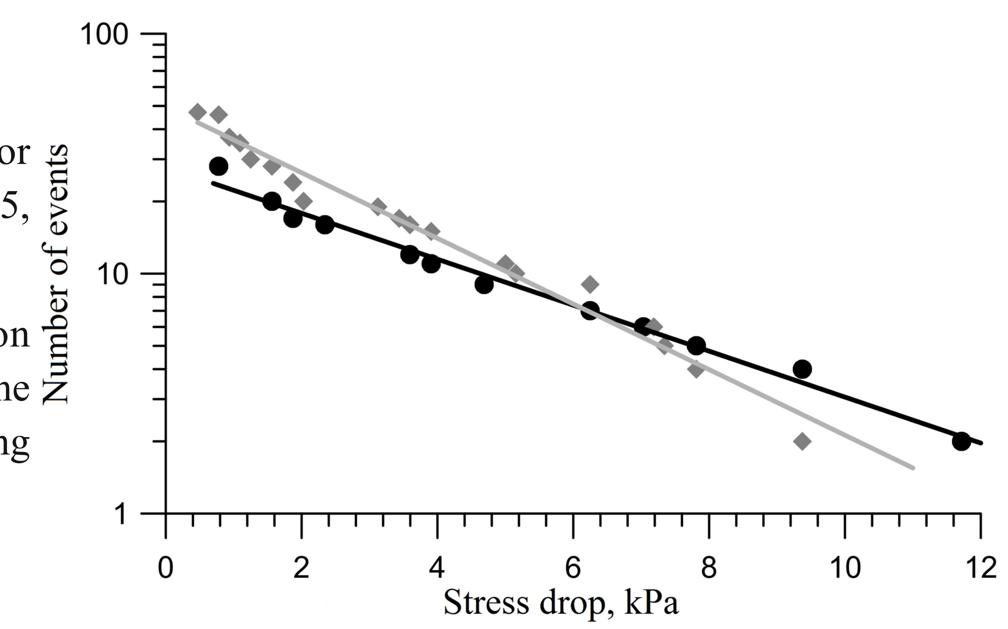


Figure 2. Magnitude-frequensy relationship for granite crumbs. Light symbol - PSD equals 0.5, Dark line - PSD equals 2

Particle size distribution (PSD) influences on magnitude-frequency pattern. The probability of the powerful dynamic events increase with increasing PSD.

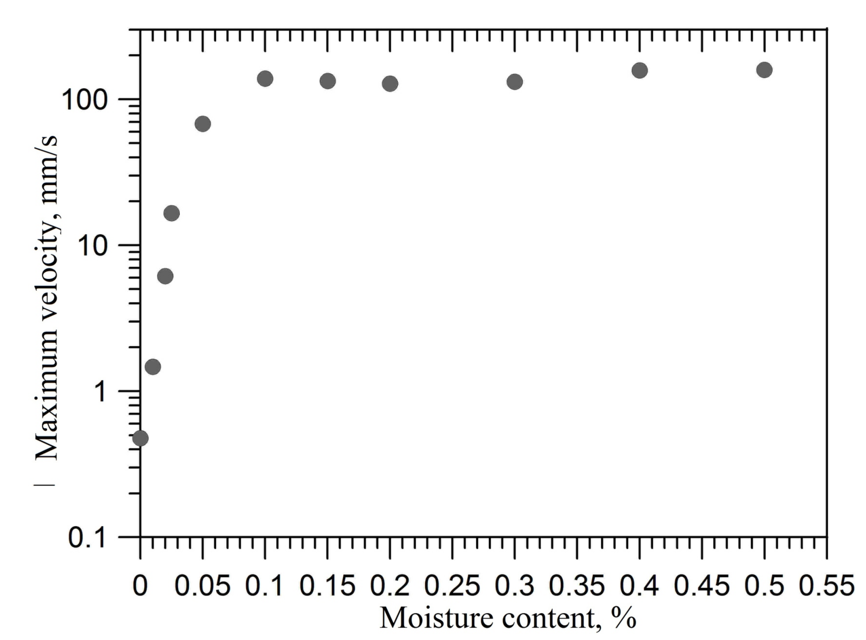
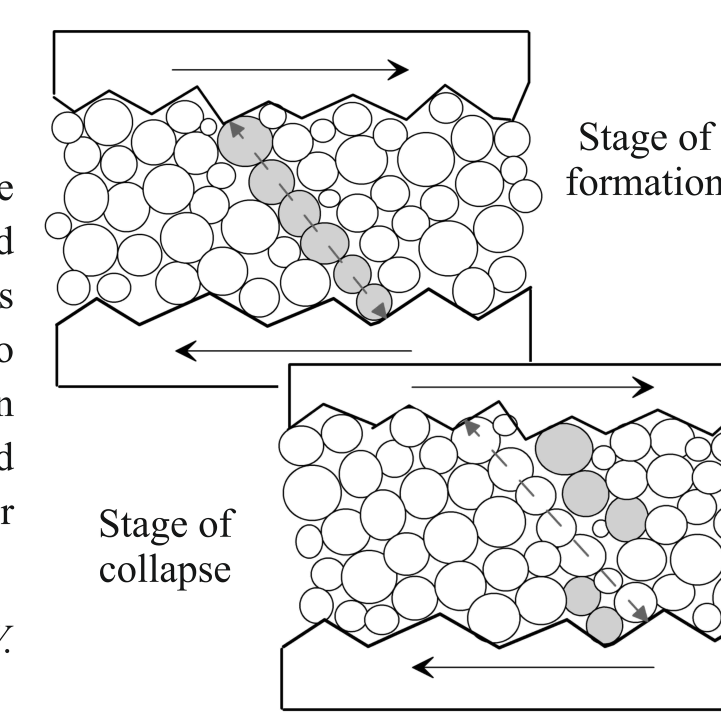


Figure 3. Maximum displacement velocity versus persantage of glycerol in sand.

The additional of only 0.1 mass % of glycerol is seen to change drastically the sliding mode: from quasi-stationary to stick-slip. Note that adding glycerol to granite crumbs haven't gave such an effect.

Possible mechanism generation of dynamic events

The occurrence of dynamic failure is related to the possible formation and collapse of force bridge of loaded particles aligned transverse to the crack. Simultaneous collapse of several bridges causes a drastic decrease in shear resistance and gives rise to dynamic instability. Hence, the ordered structure of force bridges in the medium directly influences the occurring deformation mode, and the probability of formation force bridge are determined by the order of the medium structure.



Reference: *G.G. Kocharyan, V.K. Markov, A.A. Ostapchuk, D.V. Pavlov,* (2014), Physical Mesomechanics 17 (2) (in the Press)

The effect of external action

The effects of vibration significantly depend on the mode of deformation of the contact.
In the gouge with high degree of structuring and rather weak frictional interaction between the grains, the vibrations can reduce the average amplitude of the dynamic stress drop up to almost half value. A stronger interaction between the particles in the stick-slip conditions makes the vibration action less efficient.

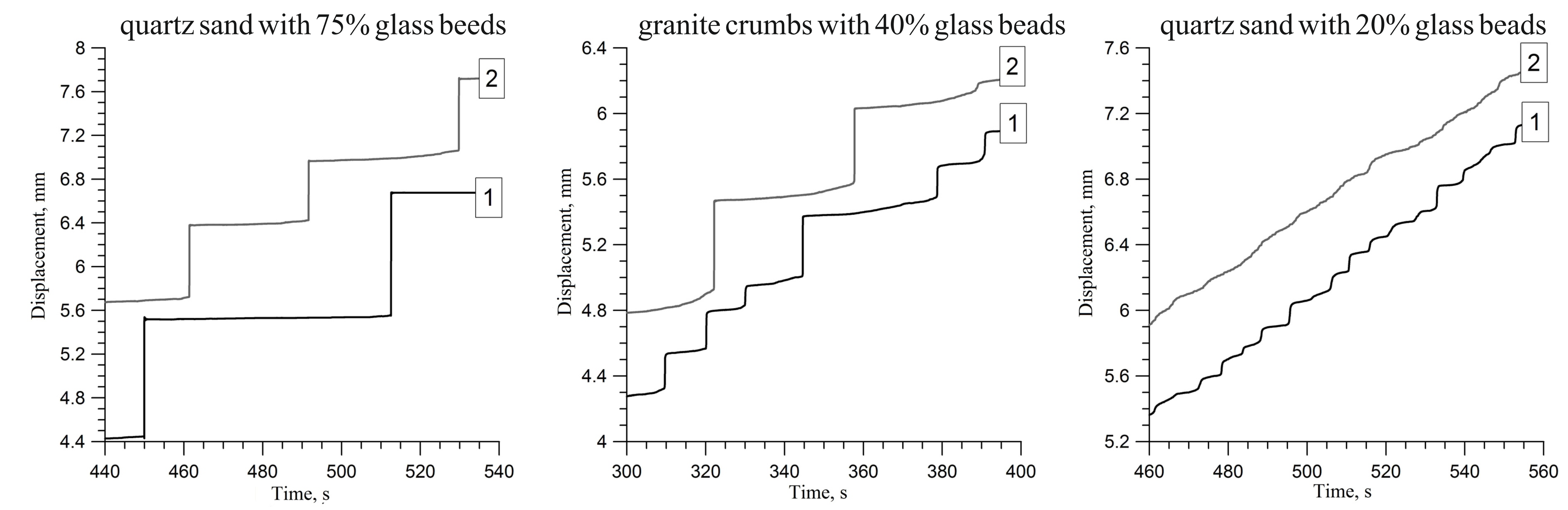


Figure 4. The time dependence of interblock displacement for the experiment (1) without vibration and (2) with vibration.

We note that the vibration action is most efficient for the translation of the low-amplitude displacements into stable sliding. In the case of quasi-stable sliding with a few low-amplitude displacements, the cumulative seismic moment released by the dynamic slips is much lower.

The other way of transforming sliding modes is *the changing of fluid viscosity of wetted gouge*.

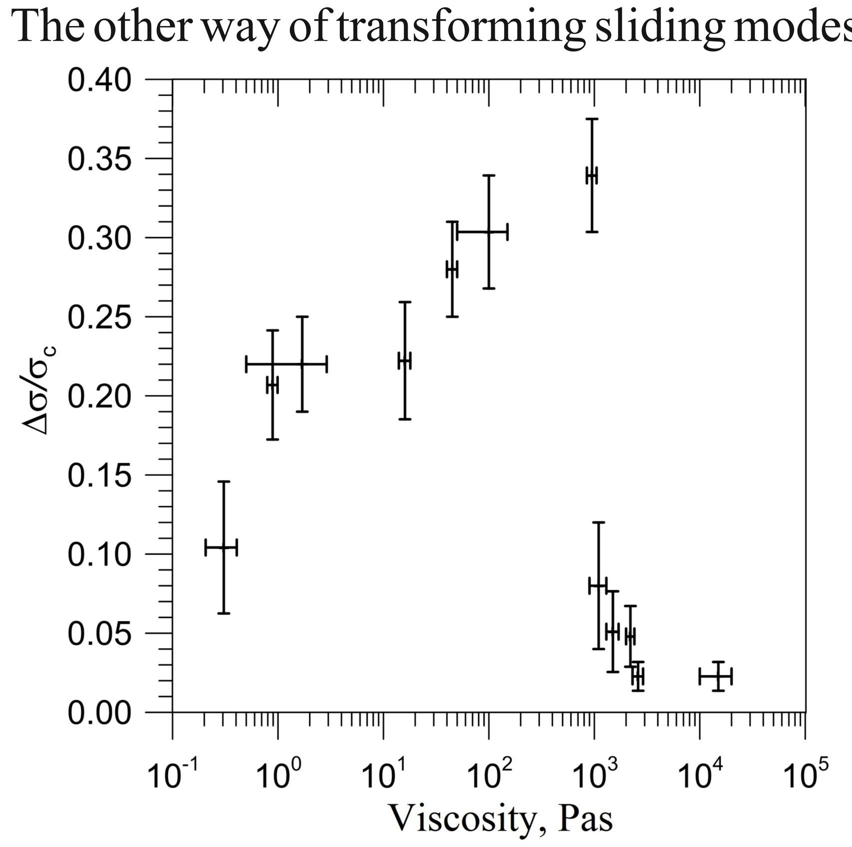


Figure 5. The influence of fluid viscosity on shear displacement.

The influence of fluid viscosity on friction interaction has threshold character. Increasing viscosity up to 1 Pas causes gradual increasing shift amplitude. Further, dramatic decrease of amplitude is observed, the relative amplitude decrease in 10 times. Thus, when the viscosity of wetting argent above a certain limit (1Pas), the sliding mode becomes quasi-stable.

Conclusions:

1. The spectrum of deformation events may occur on a discontinuity is determined by gouge structure on the mesoscale. At a slight variation of humidity, granulometric composition and grain shape, one deformation mode may change for another.
2. The effect of low-amplitude external action on the stressed interblock contact is largely determined by the background deformation regime.
3. The influence of viscosity of wetting agent on friction interaction has threshold character. Increasing viscosity up to 1 Pas causes gradual increasing stress drop. But increasing viscosity more than 1 Pas causes dramatic decrease of stress drop, and sliding mode becomes quasi-stable.

References: *G.G. Kocharyan, A.A. Ostapchuk, V.K. Markov, D.V. Pavlov,* (2014), Izvestiya, Physics of the Solid Earth 50 (3) 355-366
G.G. Kocharyan, A.A. Ostapchuk, (2014), Doklady Earth Sciences (in Press)